

# SIMBIOS Support of Ocean Color Missions & Community Infrastructure



*NASA SIMBIOS Project  
GSFC Mail Code 970.2  
Greenbelt, Maryland, USA*

<http://simbios.gsfc.nasa.gov/>

# **SIMBIOS Objectives**

**Sensor Intercomparison & Merger for Biological & Interdisciplinary Ocean Studies**

- Ensure development of internally consistent research products and time series from multiple satellite ocean color data sources
- Develop methodologies for cross-calibration of satellite ocean color sensors
- Develop methodologies for merging data from multiple ocean color missions
- Promote cooperation between ocean color projects
- Serve as a prototype for other Earth observation programs

## Mission Feedback

- Science community input
- Comparison with other appropriate products
- New Mission
- Protocol development

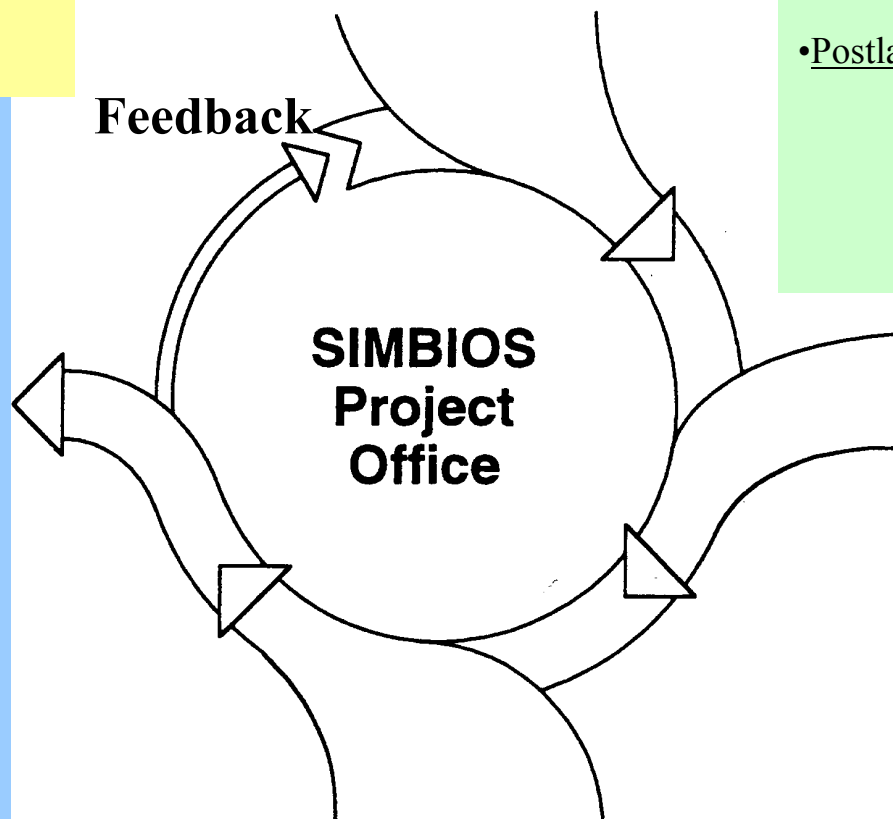
## Improved Products & Algorithms

- Reprocessing due to improvements in calibration, masks, binning schemes, product compatibilities, etc.
- New products from bio-geochemical fields, atmospheric fields, etc.
- Data distribution interface

## SeaDAS

- Satellite data processing software (CZCS, MOS, SeaWiFS, OCTS, OSMI and MODIS display)

## Satellite Data from Calibrated Sensors



## Calibration Strategy

### •Prelaunch

Lab. characterization & calibration (NIST traceable)

Solar calibration (transfer-to-orbit)

### •Postlaunch (operational adjustments)

Solar calibration (daily)

Lunar calibration (monthly)

MOBY  $L_{wn}$  time series for vicarious calibration

## *In Situ* Data

- Collection of required bio-optical and atmospheric measurements (SIMBIOS PIs)
- *in situ* instrument calibration (Project round robin NIST-traceable)
- Data collection following Ocean Optics protocols
- Maintenance of an archive of calibrated QC *in situ* data (SeaBASS)
- Calibrated instrument pool

## Product & Algorithm Validation

- Atmospheric & bio-optical algorithm validation and development (SIMBIOS PIs and project staff)
- Match-up analysis, satellite QC, time series evaluation, etc.

# Program Requirements/Activities

- Field measurement & data processing protocol definition & development
- Global bio-optical & atmospheric *in situ* data collection
- Bio-optical & atmospheric database development (SeaBASS)
- Traceability of laboratory calibration sources to standards
- Instrumented calibration sites (MOBY)
- Prelaunch sensor calibration & characterization protocols
- On-orbit calibration evaluation & methodology development
- Bio-optical & atmospheric correction algorithm development
- Product accuracy evaluation & methodology development
- Data merger algorithm development & data processing
- High volume data processing capabilities
- Technology evaluation & development
- Multi satellite data processing software
- Systematic documentation (NASATM and publications)

# Program Structure

- **SIMBIOS Science Team**

- NRA-96 (1997-2000): 21 US & 5 international investigations
- NRA-99 (2001-2003): 20 US & 14 international investigations
- MODIS Oceans Team

- **SIMBIOS Project Office**

- Co-located with SeaWiFS (1996-2003)
- Technical, program management, science team coordination & NRA support
- Technical interface with space agencies (e.g., NASDA, CNES, ESA, KARI), other organizations (e.g., NIST, IOCCG, JRC, DLR), and programs (e.g., EOS, AERONET)

# SIMBIOS Project Office *continued*

Satellite data supported (1997-2002):

- MOS-SeaWiFS cross calibration & data merger with SeaWiFS
  - German Aerospace Research Establishment (DLR)
- MOS data acquisition at NASA Wallops Flight Facility
  - Indian Space Research Organization (ISRO)
- OCTS-POLDER cross calibration
  - NASDA (Japan) & CNES (France)
- OCTS global GAC reprocessing
  - NASDA
- OSMI data processing and calibration
  - Korean Aerospace Research Institute (KARI)
- SeaWiFS calibration & product validation
- MODIS product validation & data merger with SeaWiFS (9km Chlorophyll product and diagnostic data set)
  - MODIS Oceans Team

# SIMBIOS Project Office *continued*

## Round Robin Activities

- Radiometric round-robin
  - 1997: NASA/GSFC, PML (UK), JRC (Italy), SDSU, Biospherical Instruments Inc., UCSB, NRL, DLR (Germany), NASA/WFF, Satlantic Inc. (Canada)
  - 2001: GSFC, Satlantic Inc., Biospherical Instruments Inc., HOBI Labs, UCSB, NRL, SIO
  - 2002: GSFC, Satlantic Inc., Biospherical Instruments Inc., UCSB, NRL, SIO, MOBY,USF, RSMAS, Wallops & Stennis
- Chlorophyll round-robin
  - 2000: ONR, UMD, SIO, SDSU, Bigelow, USF, NOAA & NASA/SSC
  - 2001: SDSU, UMD, CNR (Italy), LODYC (France) and BBRS
- Technology development
  - The SeaWiFS Transfer Radiometer (SXR-II) with NIST
  - SeaWiFS Quality Monitor: SQM: Satlantic & Yankee Environmental Instruments
- Protocol development & updates with science community
  - Mueller & Austin 1995, Volume 25 in the SeaWiFS Technical Report Series.
  - Fargion & Mueller 2000, Revision 2, NASA TM 2000-209966.
  - Fargion et al., 2001, AOT Protocols,NASA TM 2001-209982.
  - Mueller et al. 2002, Revision 3, NASA TM 2002-21004 (Vol1 & Vol2).
  - Mueller et al. 2003, Revision 4, in press

# SIMBIOS Project Office *continued*

## Support Services

- Sunphotometer deployment, calibration, maintenance, data processing
  - 14 Coastal Cimel stations (NASA-GSFC, AERONET)
  - PREDE MKII, SIMBAD, SIMBADA, MicroTops and MPL
- Field support
  - Satellite overflight & coverage info, real-time data
  - Over 320 field experiments supported
- International field experiments
  - INDOEX (1999)
  - ACE-Asia (2001)
  - R/V Akademik Ioffe (Atlantic Ocean and Antarctica, 2001-2002)
  - R/V Urania (Mediterranean Sea, 2002)
- Bio-optical data archival & distribution
  - SeaBASS
  - NODC
- Satellite data processing (SeaDAS)
  - CZCS, MOS, SeaWiFS, OCTS, OSMI and MODIS display

# **SIMBIOS Project Staff**

## **Satellite Data Processing**

Bryan Franz, Joel Gales, Sean Bailey, Jeremy Werdell and SeaWiFS staff

## **Data Merging**

Ewa Kwiatkowska-Ainsworth and Bryan Franz

## **Satellite Characterization**

Bob Barnes and Bryan Franz

## **Support Services**

Sean Bailey, Jeremy Werdell, Christophe Pietras and Kirk Knobelspiesse

## **Data Product Validation**

Sean Bailey, Jeremy Werdell, Christophe Pietras and Kirk Knobelspiesse

## **Calibration Round Robin**

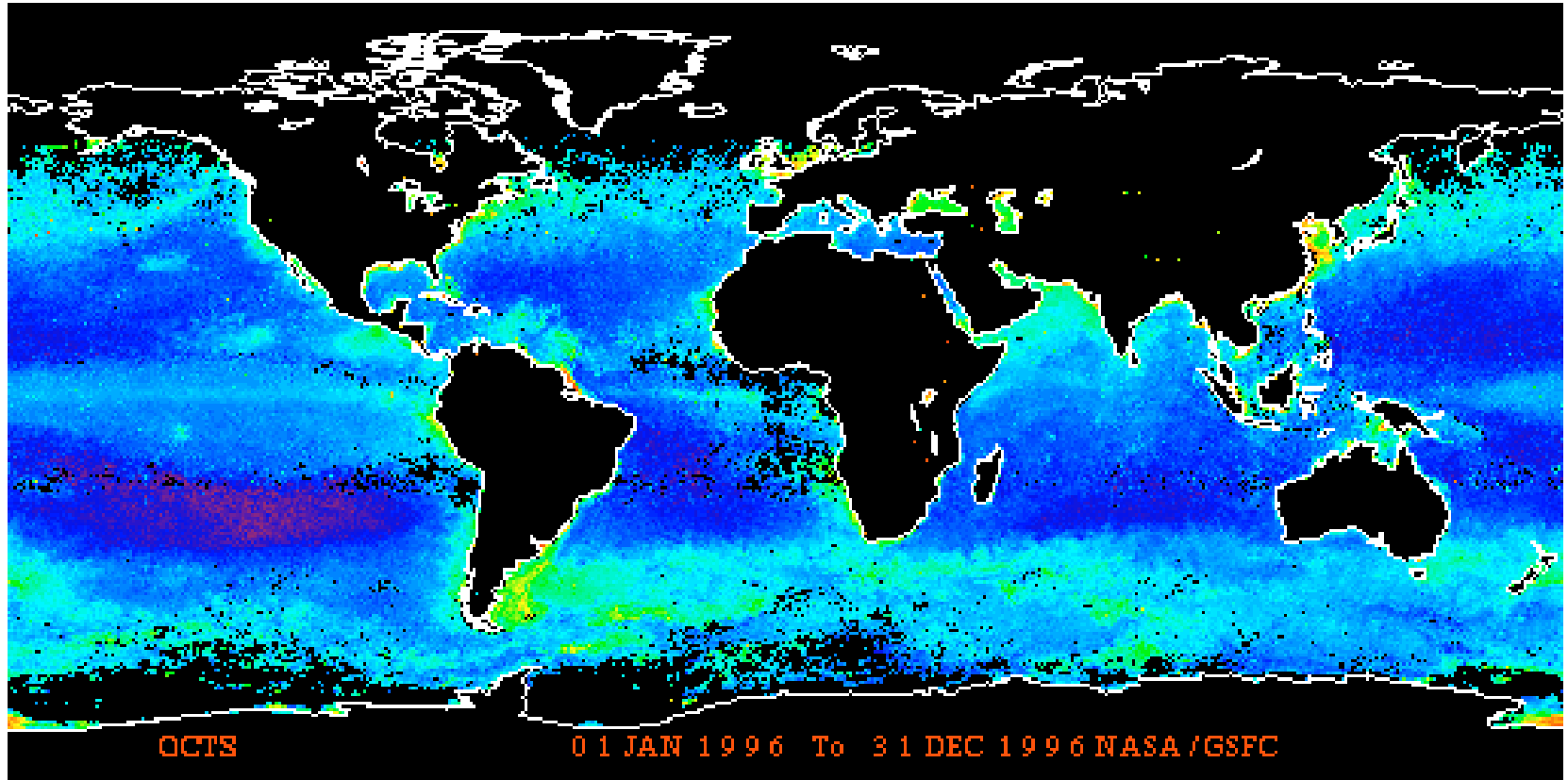
Gerhard Meister and Bob Barnes

# SIMBIOS Software Development Activities

- Primary focus has been on generalization of SeaWiFS science processing software and data processing system to support multiple sensors.
- Includes Level-1 to Level-2 (MSL12), space and time bidders, mappers, etc., with distributed processing on a multi-platform system under SyBase control.
- Level-1 through Level-3 processing capabilities for SeaWiFS, OCTS, MOS, POLDER, OSMI.
- Software widely used and distributed through SeaDAS.
- Full support for MODIS (Terra and Aqua) underway.

# Retrospective Satellite Data Processing

## Reprocessing of OCTS GAC Mission Archive



- Complete reprocessing of 9-month mission archive using SeaWiFS algorithms and formats, data distributed through Project and DAAC.
- SeaDAS 4.03p released November 2001 supports OCTS GAC.

[http://seawifs.gsfc.nasa.gov/SEAWIFS/RECAL/OCTS\\_Repro1/](http://seawifs.gsfc.nasa.gov/SEAWIFS/RECAL/OCTS_Repro1/)

# Data Merger

## Algorithm Development and Evaluation

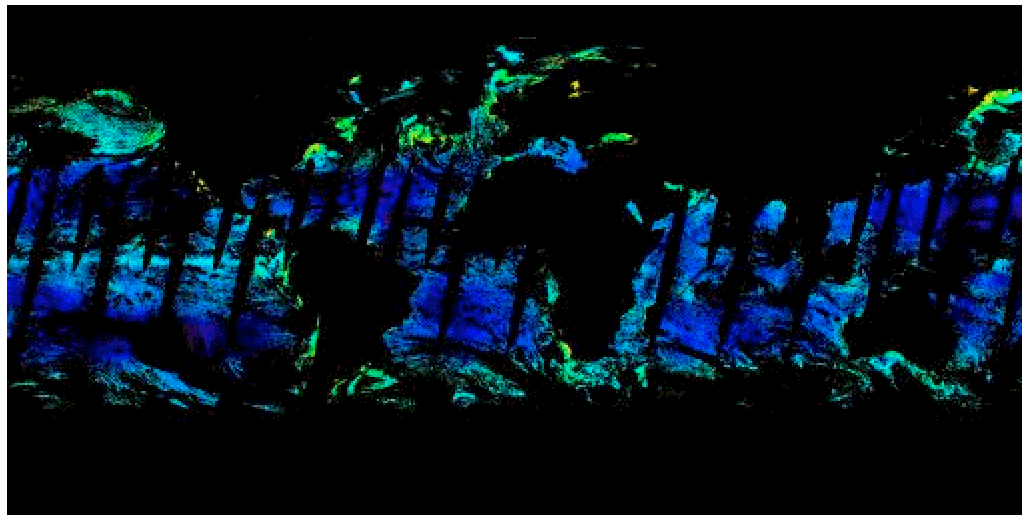
- blended analysis (W. Gregg, SIMBIOS PI).
- semi-analytical optical approach (S. Maritorea, SIMBIOS PI).
- spatial/temporal interpolation – statistical objective analysis (SIMBIOS Project Office).
- regression mapping – backpropagation neural networks and support vector machines (SIMBIOS Project Office).
- averaging and **weighted averaging** (SIMBIOS Project Office).

# Operational Data Merger

## MODIS & SeaWiFS Daily Merged Products

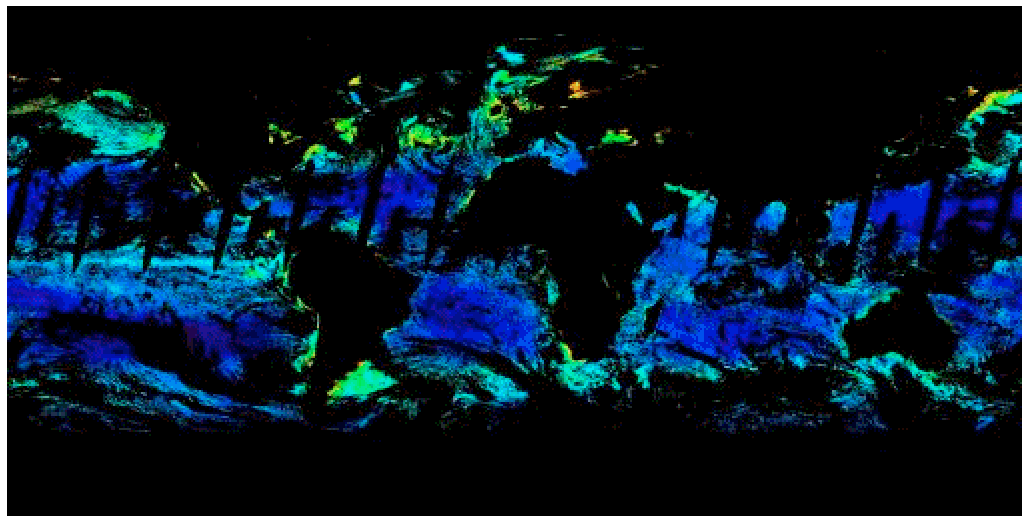
### MODIS

Standard 4.6-km Level-3 binned chlor\_a\_2 product at quality 0. Mapped to  $\sim 0.087^\circ$  Plate Carre.



### SeaWiFS & MODIS

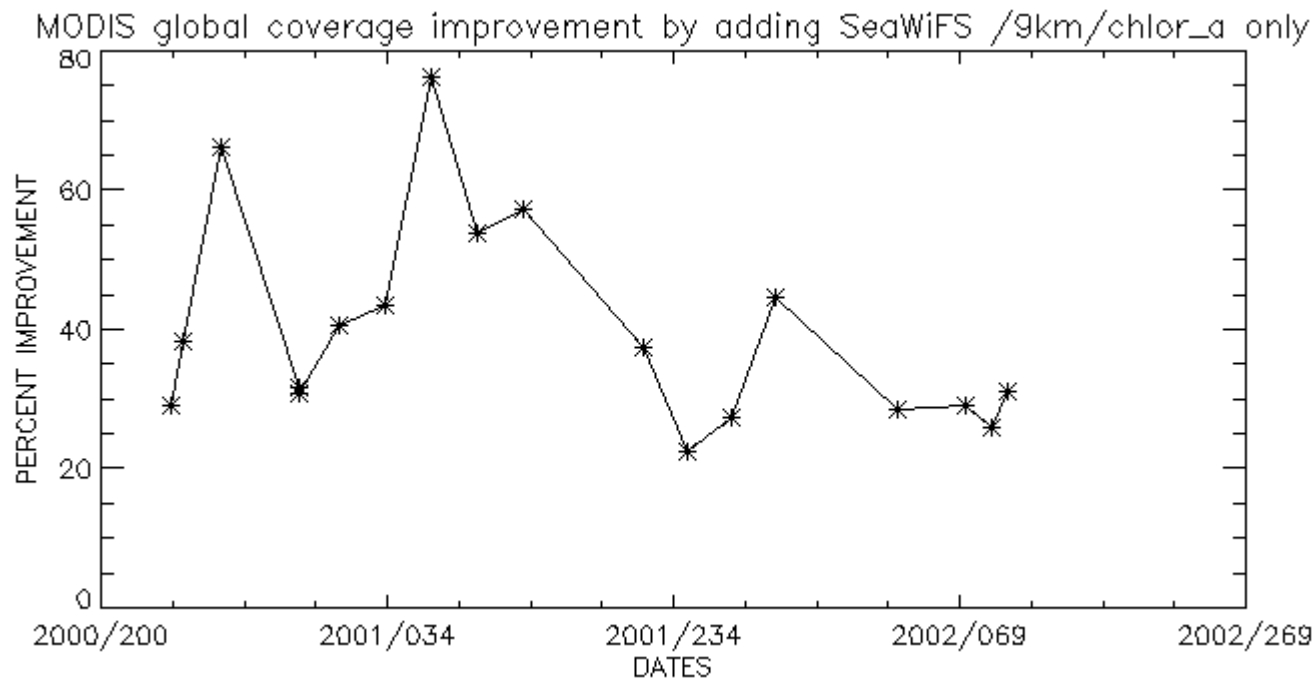
MODIS 4.6 km product converted to 9-km SeaWiFS format merged with standard SeaWiFS 9-km Level-3 chlor\_a bin product, then mapped.



<http://simbios.gsfc.nasa.gov/staff/franz/merge/>

# Increase in Global Daily Chlorophyll Coverage

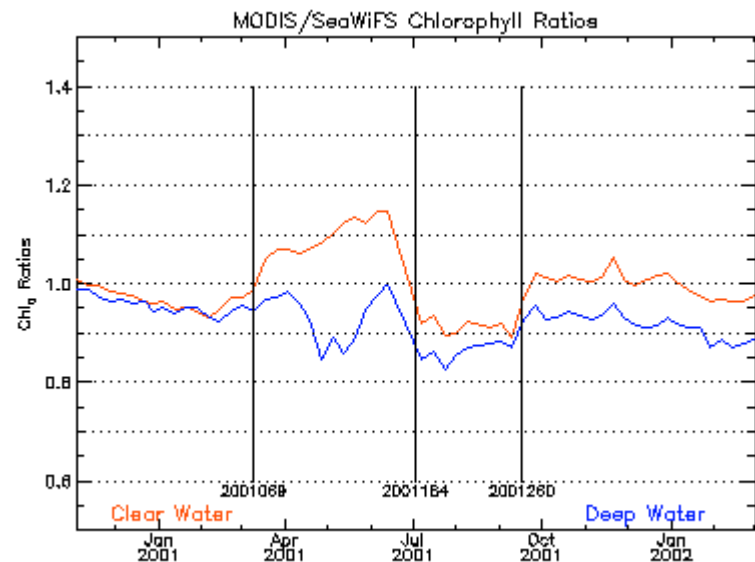
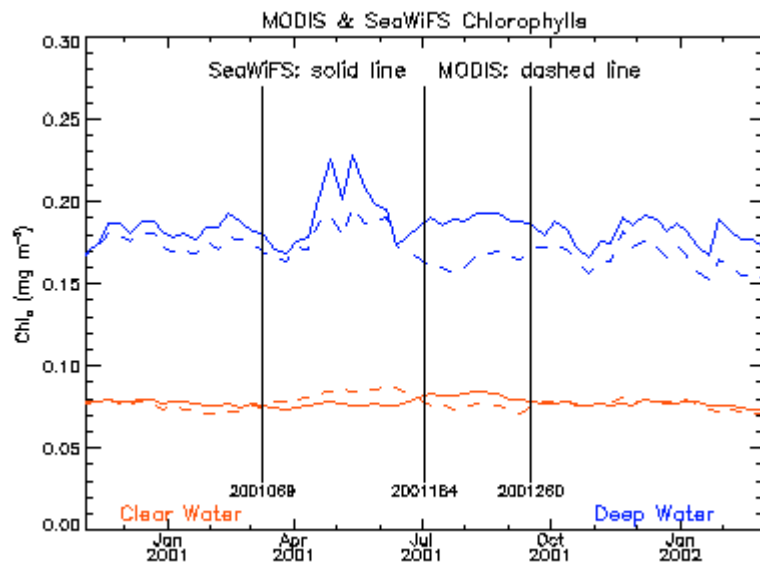
## SeaWiFS added to MODIS



# Satellite Instrument Characterization

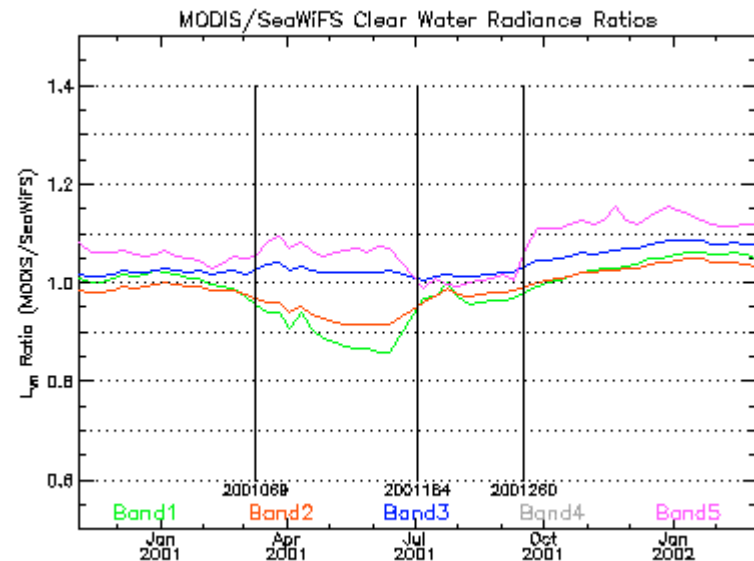
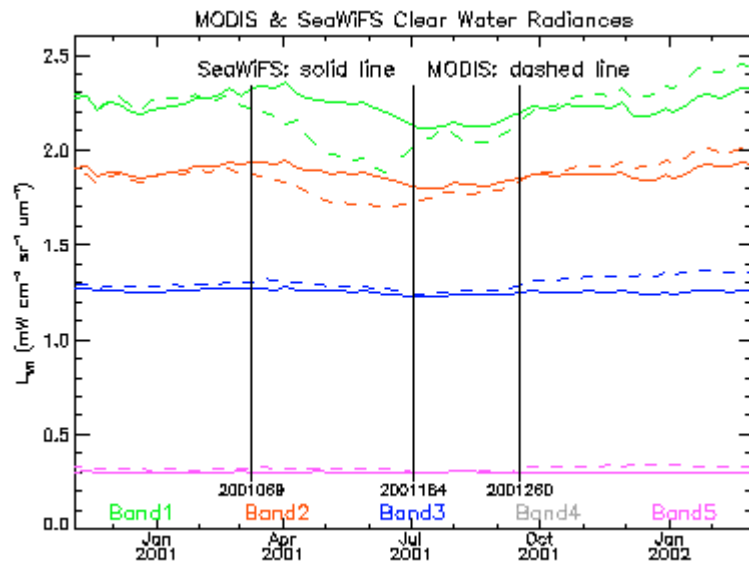
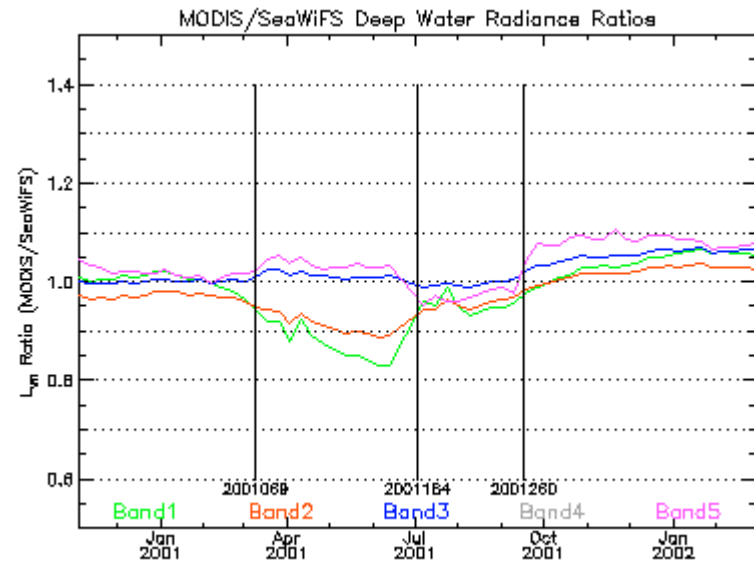
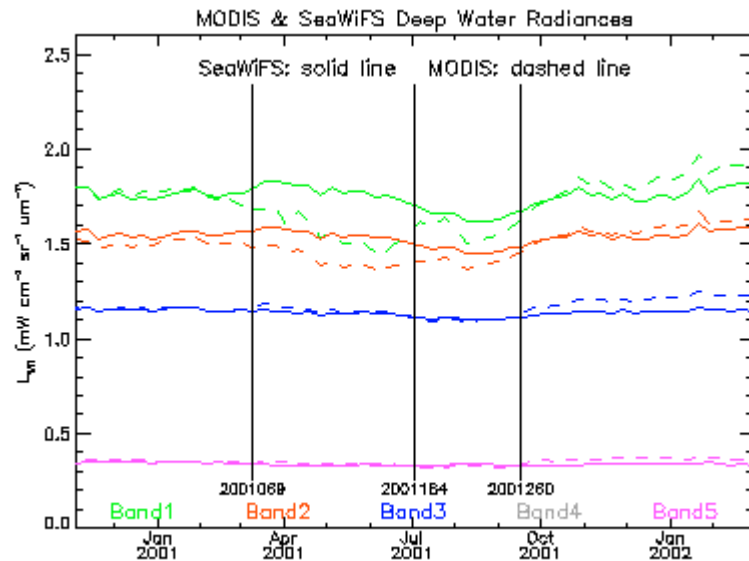
## MODIS and SeaWiFS Temporal Trending

- Trending derived from 8-day Level-3 binned products at 9-km.
- Deep water includes all bins where water depth exceeds 1000 meters.
- Clear water includes all deep water bins where retrieved chlorophyll is less than  $0.15 \text{ mg m}^{-3}$  (both sensors).
- Only common bins are included in the trended averages.



[http://simbios.gsfc.nasa.gov/staff/franz/l3trend/modis\\_seawifs/](http://simbios.gsfc.nasa.gov/staff/franz/l3trend/modis_seawifs/)

# MODIS and SeaWiFS Temporal Trending



# MODIS and SeaWiFS Temporal Trending

## Cumulative Statistics

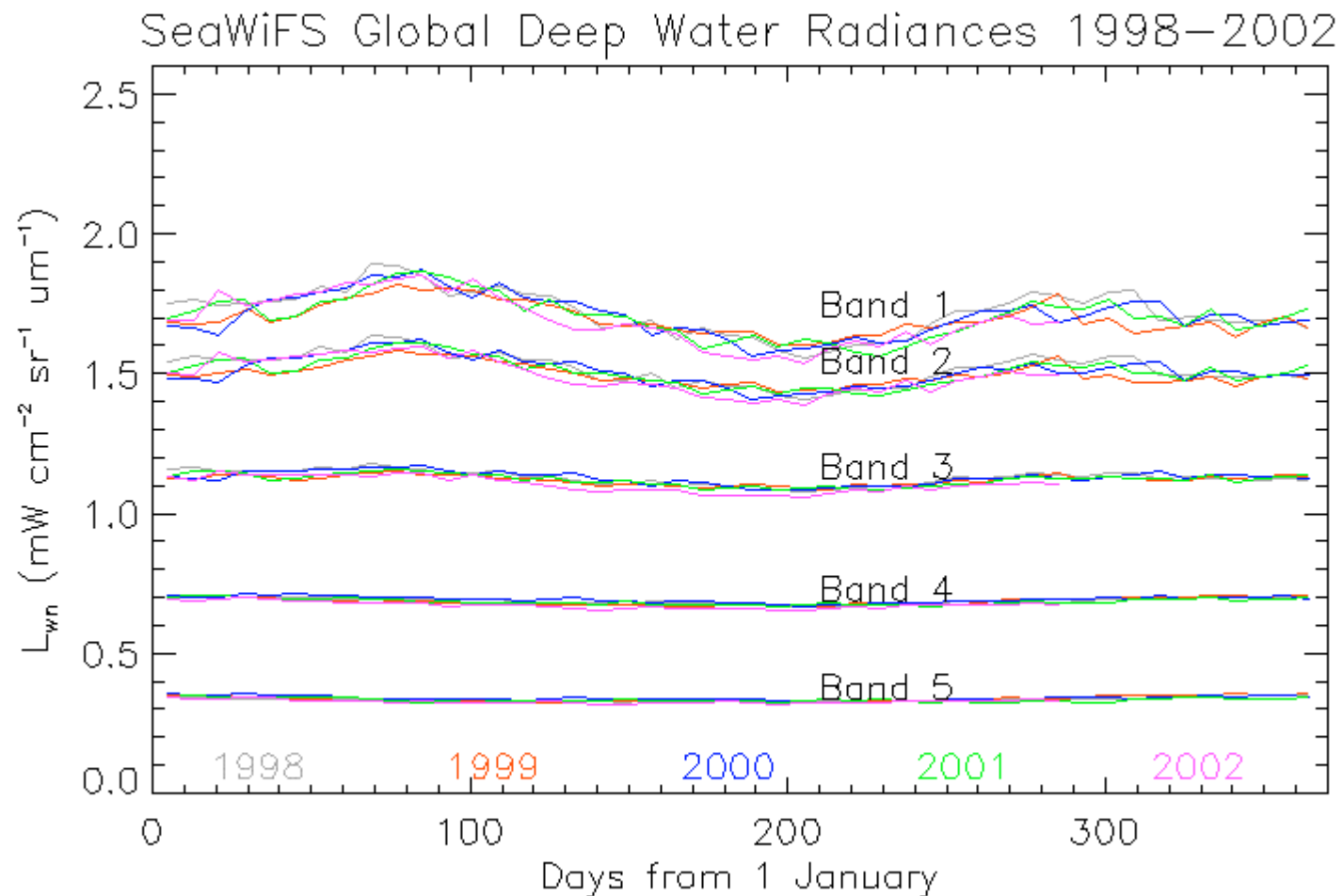
Sensor	Subset	Chlor_a	Chlor_a	nLw_412	nLw_412	nLw_443	nLw_443	nLw_490	nLw_490	nLw_555	nLw_555
		mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev
SeaWiFS	Clear	0.077	0.0025	2.235	0.0584	1.878	0.0363	1.253	0.0119	0.299	0.0035
MODIS	Clear	0.077	0.0042	2.210	0.1391	1.858	0.0825	1.302	0.0339	0.322	0.0112
SeaWiFS	Deep	0.185	0.0118	1.753	0.0526	1.539	0.0354	1.140	0.0181	0.339	0.0075
MODIS	Deep	0.171	0.0099	1.720	0.1306	1.500	0.0796	1.166	0.0396	0.352	0.0149
SeaWiFS	Coastal	0.885	0.1549	0.844	0.0614	0.902	0.0459	0.884	0.0369	0.431	0.0249
MODIS	Coastal	0.743	0.1227	0.882	0.0759	0.877	0.0536	0.896	0.0389	0.436	0.0240

- Chlorophyll and nLw in good agreement, on average.
- Variability of MODIS temporal trends is 2 to 3 times larger than that measured for SeaWiFS (standard deviation relative to mean).
- SeaWiFS temporal variability calibrated through Lunar observation, and demonstrated through annual repeatability in temporal trends.

[http://simbios.gsfc.nasa.gov/staff/franz/l3trend/modis\\_seawifs/](http://simbios.gsfc.nasa.gov/staff/franz/l3trend/modis_seawifs/)

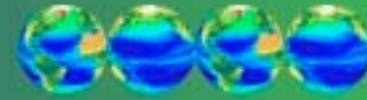
# SeaWiFS Annual Repeatability

## Deep Water Temporal Trends



# SeaBASS

*The SeaWiFS Bio-optical Archive and Storage System*



## HIGHLIGHTS

Local archive for bio-optical data and related oceanographic and atmospheric measurements

Data contributed by research groups from 43 institutions in 14 countries

Data uses include:

- (1) satellite ocean color data product validation
- (2) bio-optical algorithm development
- (3) climate, time series, and merger studies

31,000 data files from over 1,100 field campaigns, as of September 2002, including:

- (1) 10,000 continuous depth profiles
- (2) 220,000 phytoplankton pigment concentrations
- (3) 14,000 spectrophotometric scans
- (4) 13,000 discrete measurements of aerosol optical thickness

All data are accessible online:

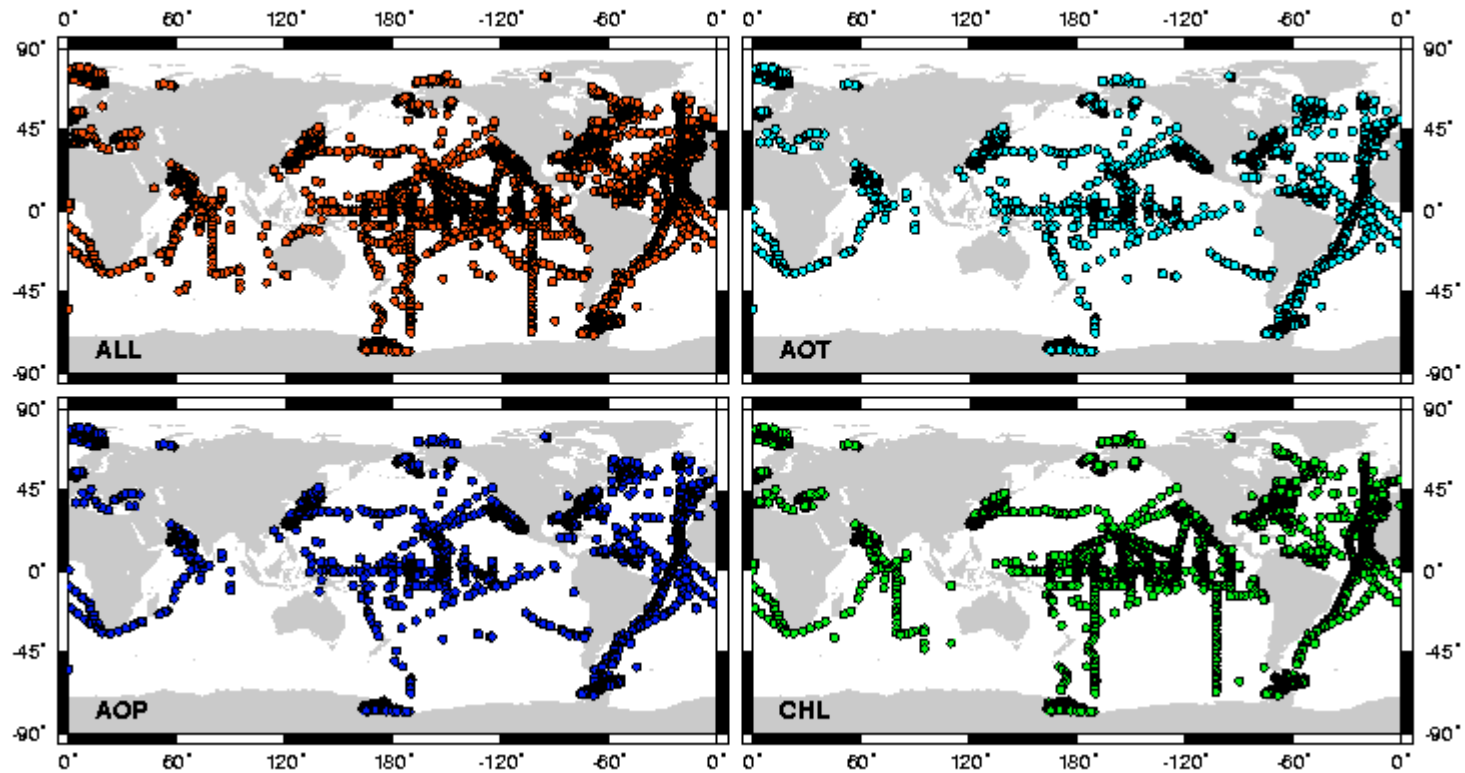
- (1) full access restricted to NASA-funded researchers
- (2) all data collected prior to 31 December 1999 publicly available
- (3) public data contributed to NOAA NODC

Over 62,000 data files distributed from 1 January to 31 July 2002

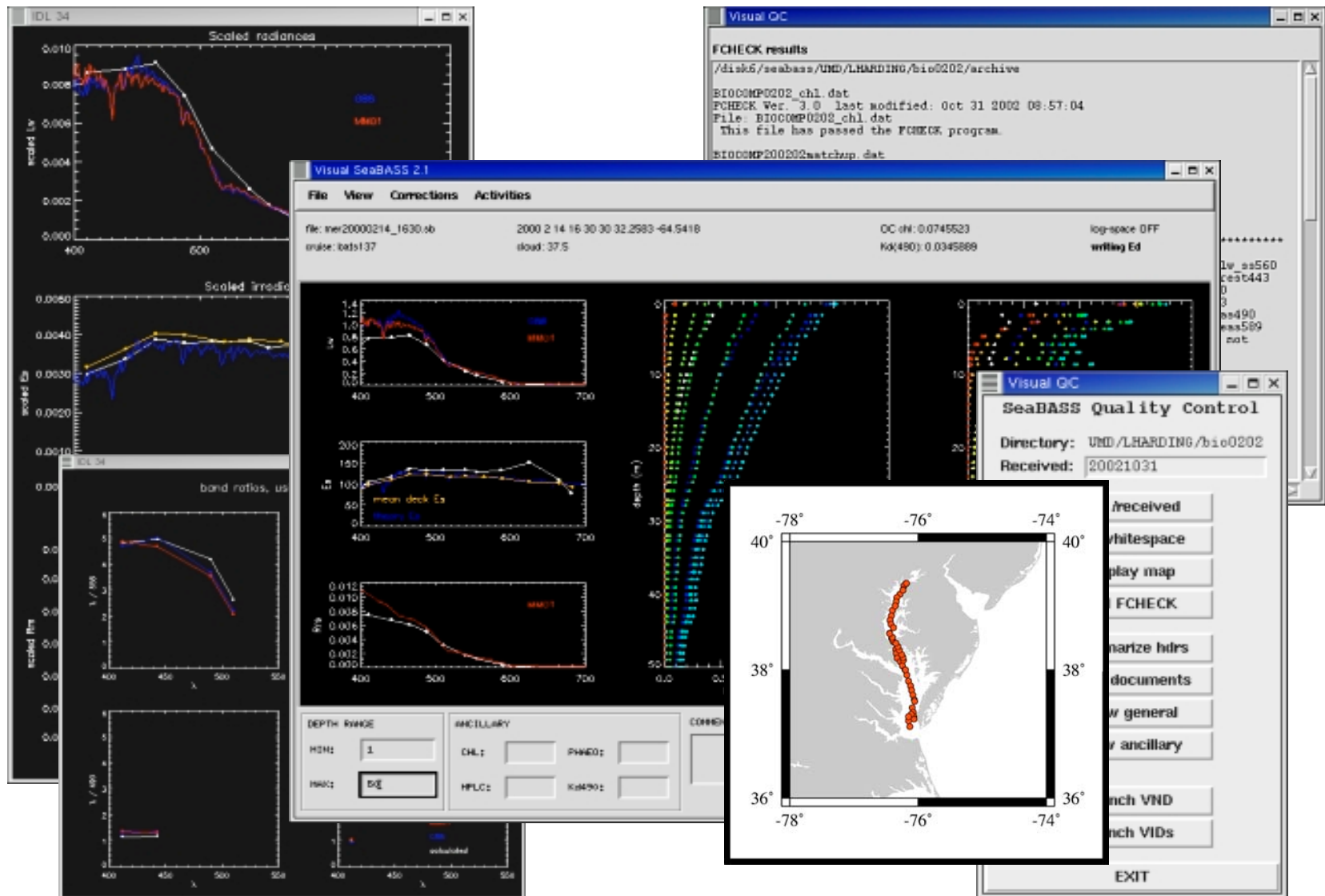
See also NASA/TM-2002-211617, published this September

<http://seabass.gsfc.nasa.gov>

## SeaBASS Bio-optical Data Set



The global distribution of various data parameters archived in SeaBASS, as of October 2002.



Various tools and utilities used to evaluate bio-optical data submitted to SeaBASS.

SeaBASS Bio-optical Database - Galeon

File Edit View Tab Settings Go Bookmarks Tools Help

90 http://seabass.gsfc.nasa.gov/prob/image.cgi

## Search the SeaBASS

ENTER QUERY KEYWORD(S) (for example: CHL)

CHL

Apply keyword search to: ☐ affiliation ☐ investigator

Apply search conditions: 'ALL' requires that all keywords be located.

**LIMIT BY DATA TYPE:**

Select data type: pigment

**LIMIT BY DATE:**

Select either a date range (returns all data collected within the date range) or a climatological range (returns only data collected in the date range)

Start: Jan 1 1999 End: Oct 31 2002

Month: Jan Start year: 1975 End year: 1999

**LIMIT BY LOCATION** (positive values are north of the equator)

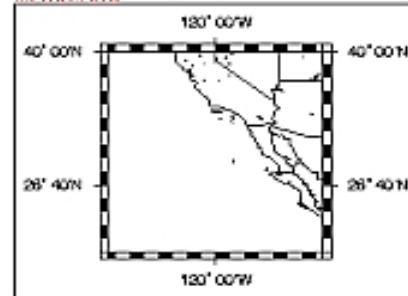
North (+/- 90.0): 40.0 South (+/- 90.0): 20.0

West (+/- 180.0): -130.0 East (+/- 180.0): -110.0

SUBMIT QUERY HELP CLEAR

Keywords: CHL  
Applied to: field  
Data type: pigment  
Dates: Jan 1, 1999 to Oct 31, 2002  
North: 40.0  
South: 20.0  
West: -130.0  
East: -110.0

The search area:



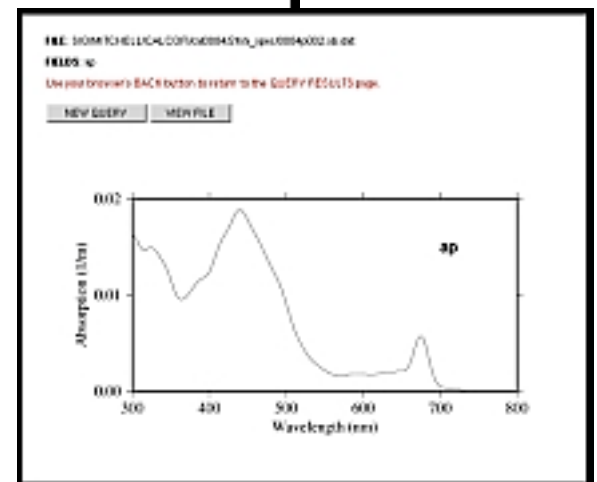
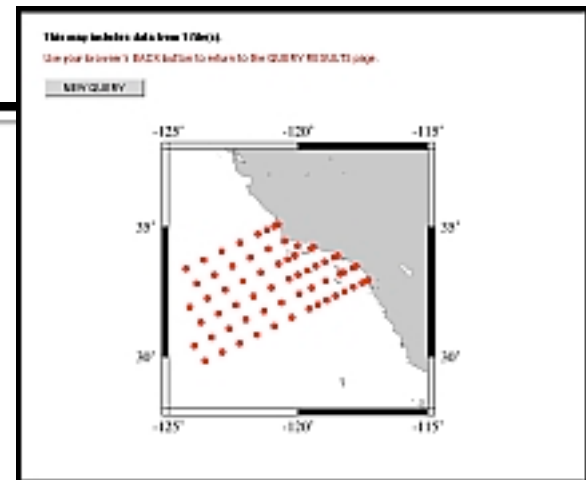
NEW QUERY HELP CLEAR

88 matching files found.

UCSE/CRSED/PnBGK/bottles/020428\_pbl134\_bot.sb  
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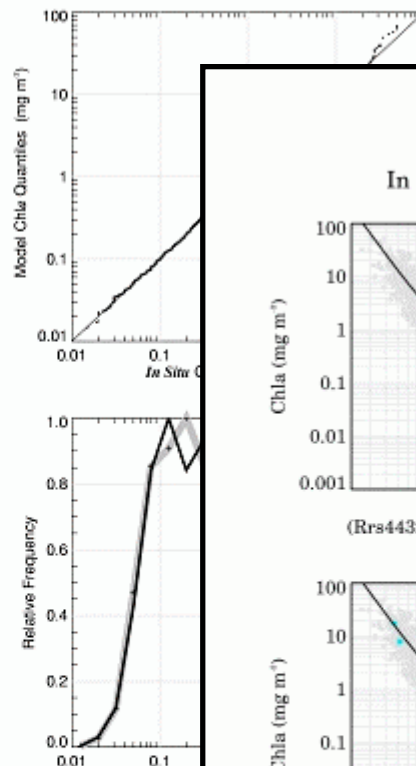
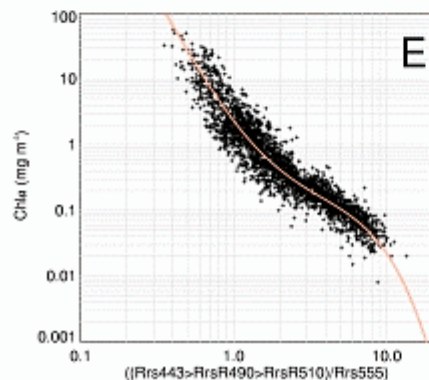
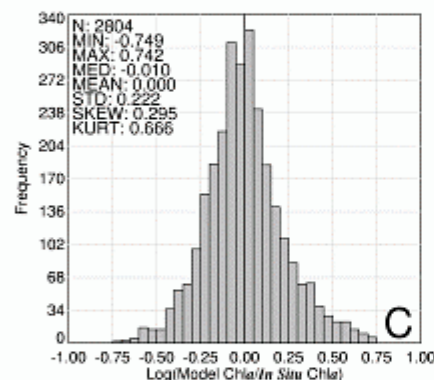
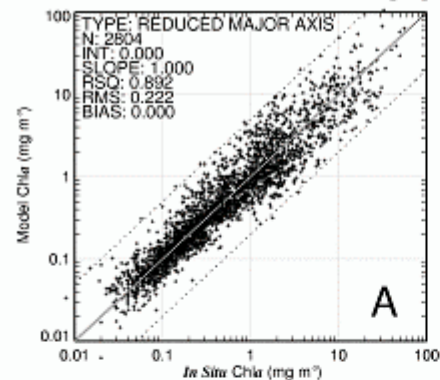
☐ SELECT ALL FILES

VIEW FILE SAVE FILES LIST DOCUMENTS PLOT FILE MAP FILES



The full bio-optical data set is available online, using a variety of search engines and utilities.

## OC4 v4

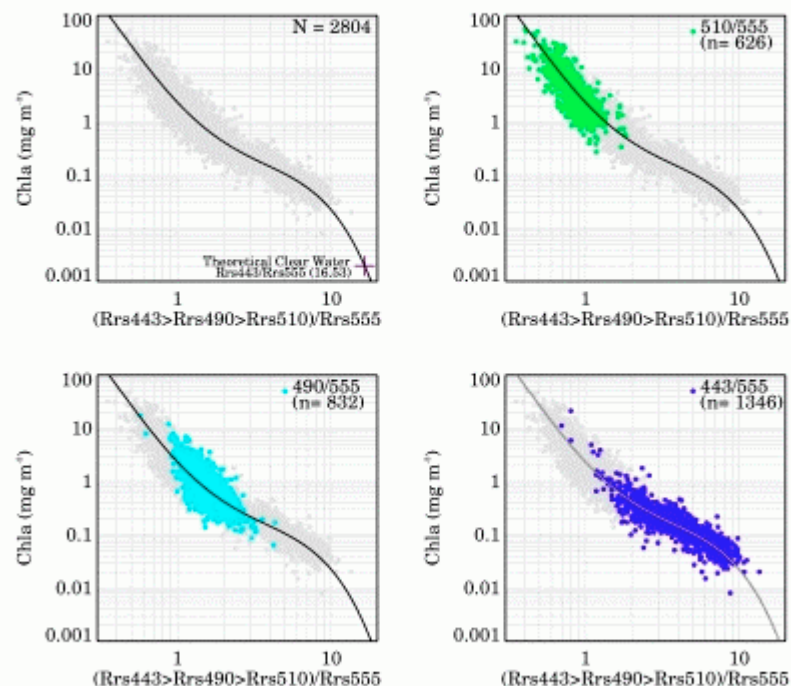


$$\text{Chla} = 10^{(0.366 - 3.067 \cdot R)}$$

$$R = \log_{10}((\text{Rrs443} > \text{Rrs490} > \text{Rrs510}) / \text{Rrs555})$$

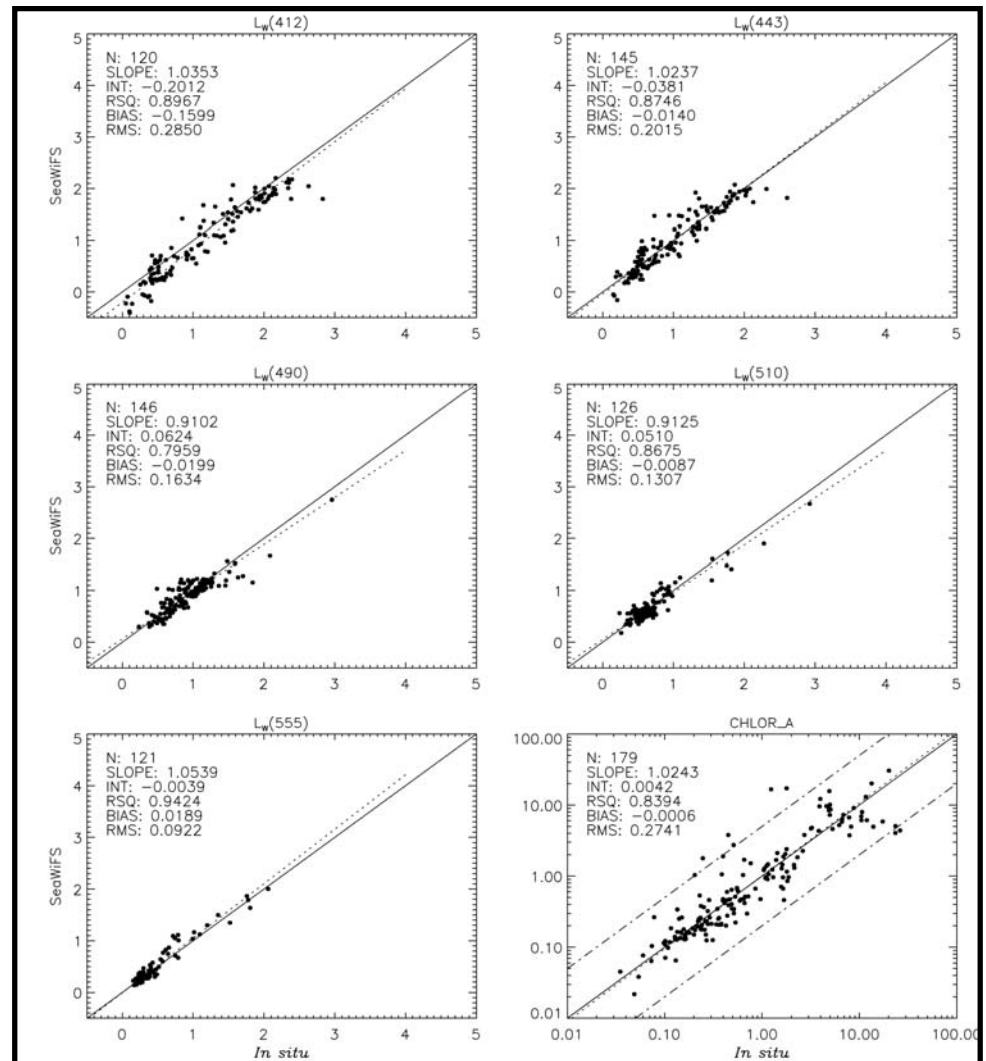
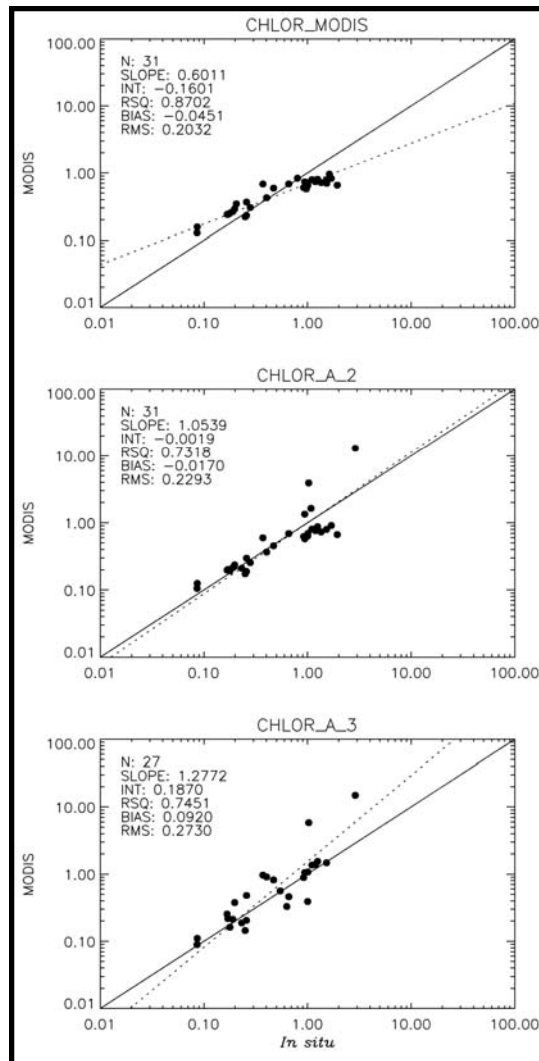
## OC4 v4 Algorithm

In Situ Maximum Band Ratio versus Chlorophyll a



**Example analyses (1): bio-optical algorithm development.**

*Plots courtesy of John E. O'Reilly, NOAA*



**Example analyses (2): satellite data product validation.**

# SIMBIOS Instrument Pool



MPL

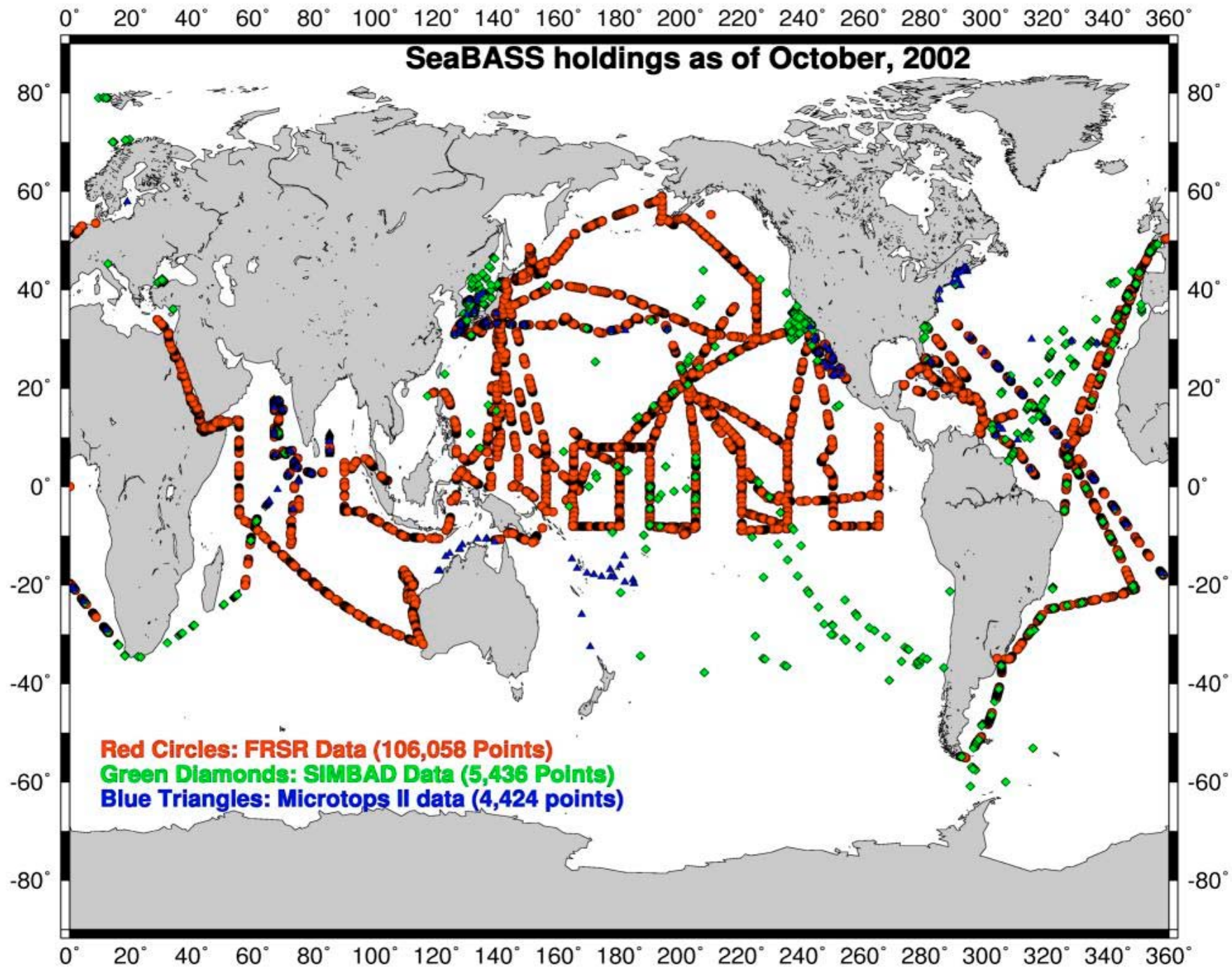


Microtops II

SIMBADA

- Microtops II Sun Photometer (14)
  - **Hand held sun photometer, bands at 440, 500, 675, 870 and 936nm**
  - **Calibrated regularly (every 90 days) with respect to AERONET CIMELs**
- SIMBAD Sun Photometer/Above water radiometer (2)
  - **Hand held sun photometer and above water radiometer with bands at 443, 490, 560, 670 and 865nm**
  - **Calibrated regularly (every 90 days) with respect to AERONET CIMELs**
- SIMBADA Sun Photometer/Above water radiometer (2)
  - **Hand held sun photometer and above water radiometer with bands at 350, 380, 412, 443, 490, 510, 565, 620, 670, 750 and 865nm**
  - **Calibrated regularly (every 90 days) with respect to AERONET CIMELs**
- Fast Rotating Shadowband Radiometer (FRSR)
  - **Automated Shadowband Radiometer deployed by the Brookhaven National Laboratory (Dept. of Energy) as part of the Portable Radiation Package (PRP)**
  - **Measures sky radiance and AOT at 410, 500, 615, 680 and 870nm**
- Micro-Pulse LIDAR (MPL)
  - **Autonomous Eye safe LIDAR at 523nm**
- CIMEL Sun Photometer (14)
  - **Land based sun photometers, given to AERONET project in 2002**

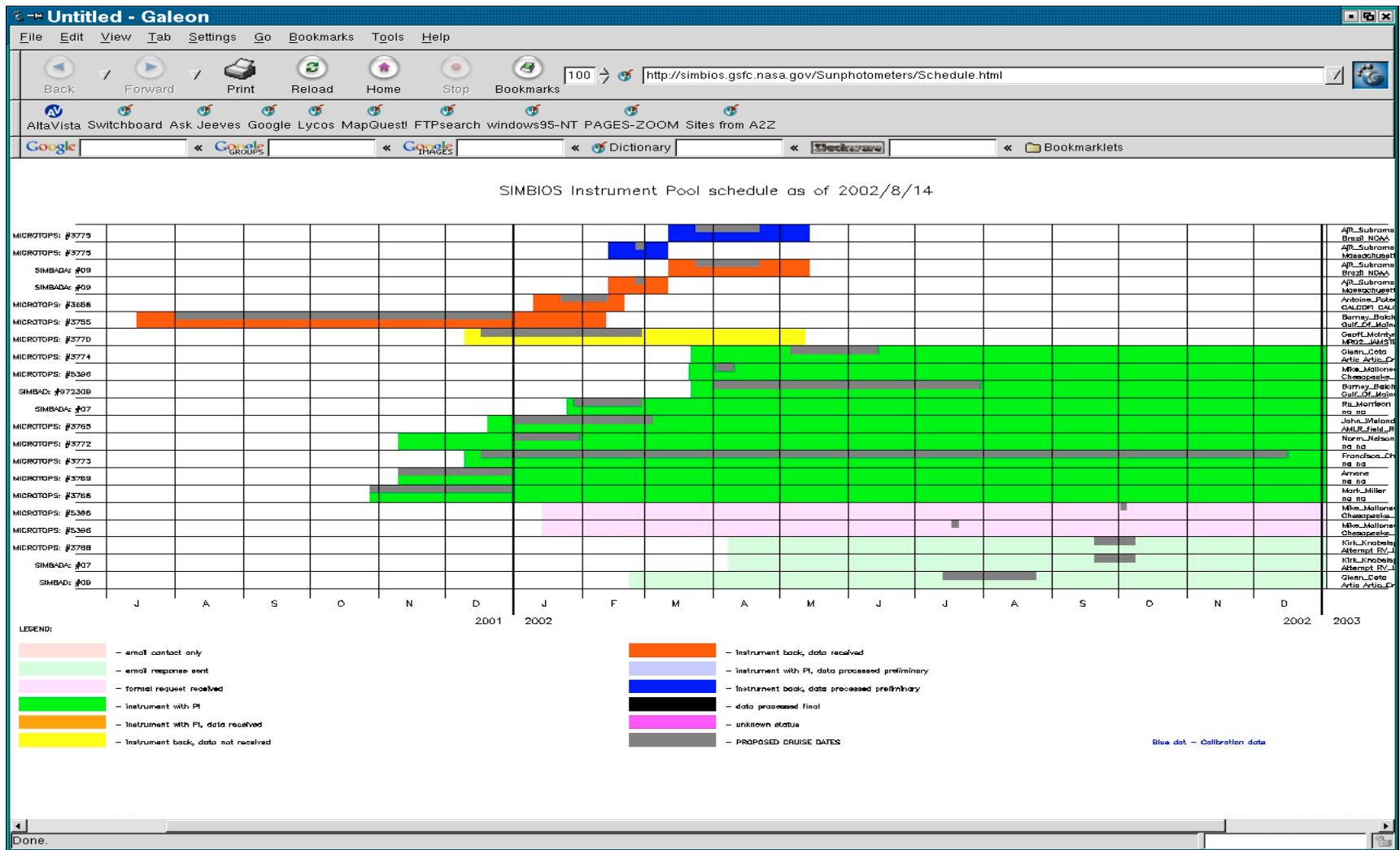
# SeaBASS holdings as of October, 2002



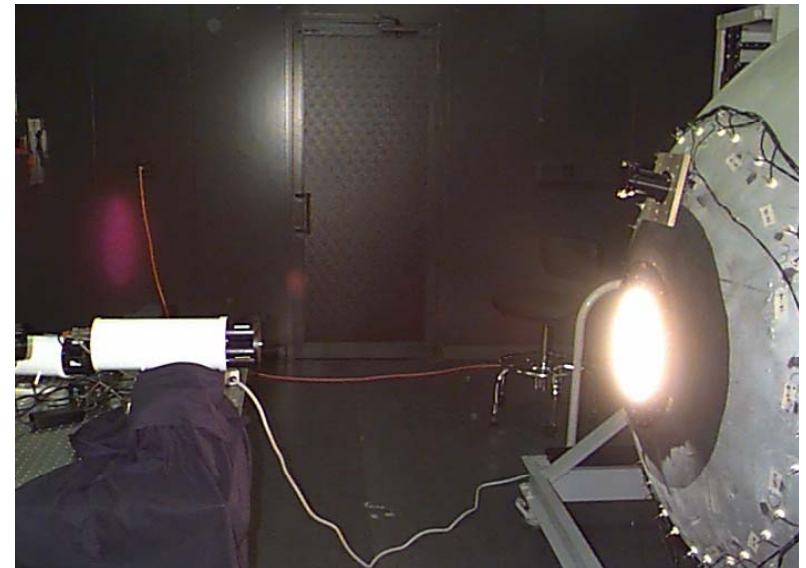
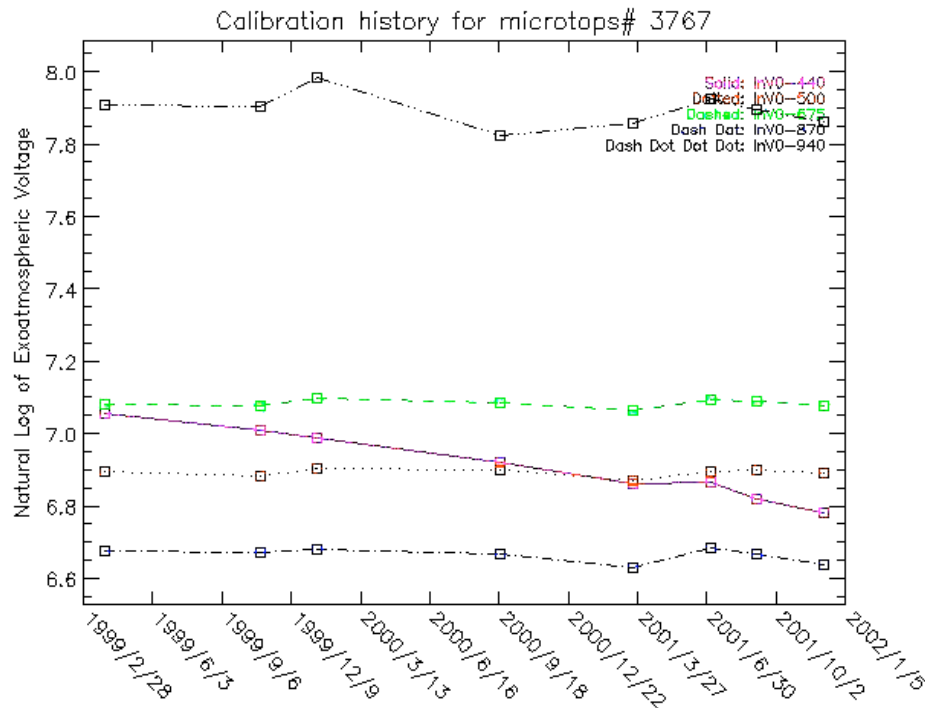
# SIMBIOS Instrument Pool Calibration and Scheduling

- Hand held instruments calibrated every three to six months.
- Calibration and deployment tracked on the SIMBIOS web site

<http://simbios.gsfc.nasa.gov/Sunphotometers/schedule.html>



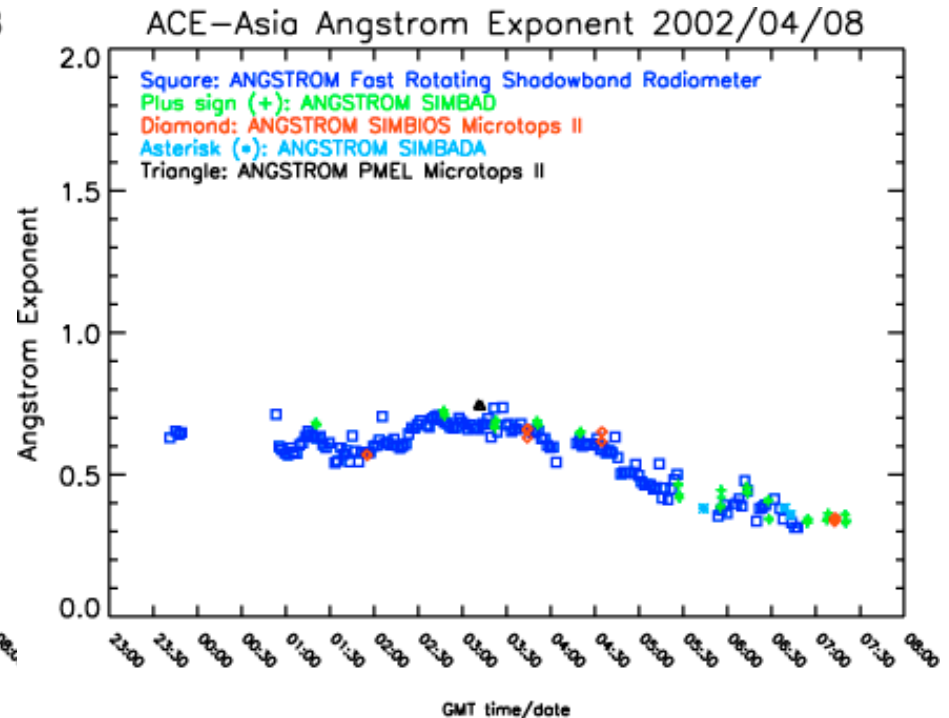
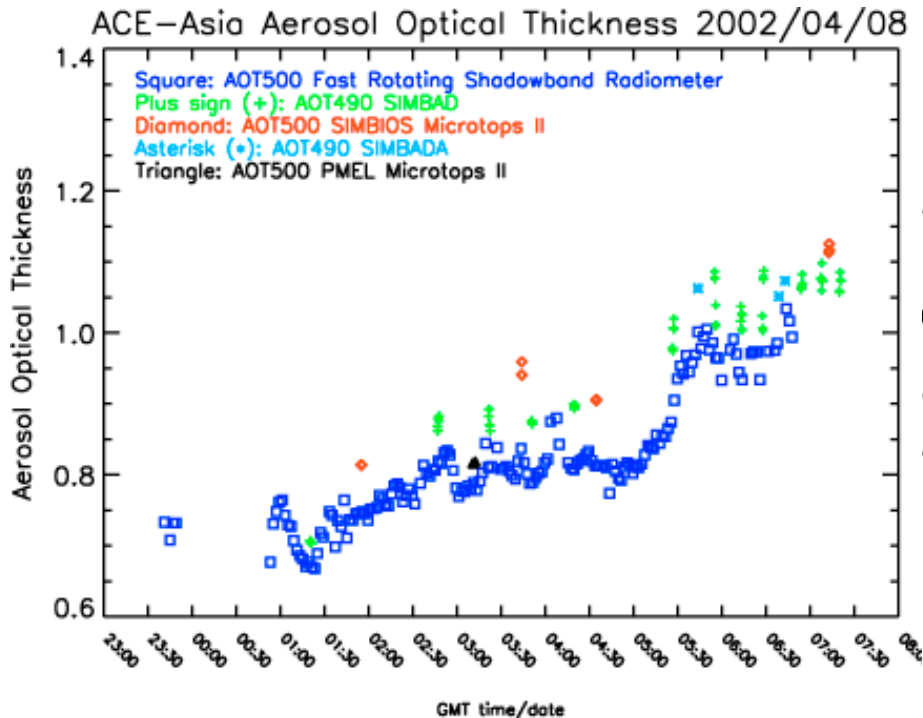
# Sun Photometer Calibration Activities



- Roof platform at GSFC used to transfer AERONET CIMEL calibration to SIMBIOS sun photometers
- SIMBIOS Project has done ~ 55 instrument calibrations per year
- Hardy 6' integrating sphere (GSFC Code 920.1) used to calibrate SIMBIOS radiometers at low gains

# ACE-Asia data validation efforts

- ACE-Asia was ideal to validate data from a variety of sun photometers
  - Instruments: FRSR, SIMBAD, SIMBADA and two Microtops II's
  - Calibration was performed by a variety of means
  - Encountered a variety of aerosol conditions: from low AOT Maritime conditions off Hawaii to extremely high AOT dust events close to Korea.
- Hand held sun photometer AOT and Angstrom Exponent values agree within uncertainties in all situations, although Angstrom uncertainty values are large



# SIMBIOS aerosol data analysis

- Several improvements in the last year have brought the SIMBIOS Aerosol dataset to maturity:

- Uncertainty analysis performed upon Microtops II, FRSR, SIMBAD and SIMBADA

- New measurement protocol with the Microtops II effectively removes sun pointing errors

- Screening performed on previously captured Microtops II data to remove sun pointing errors

- Continuation of data collection and calibration efforts

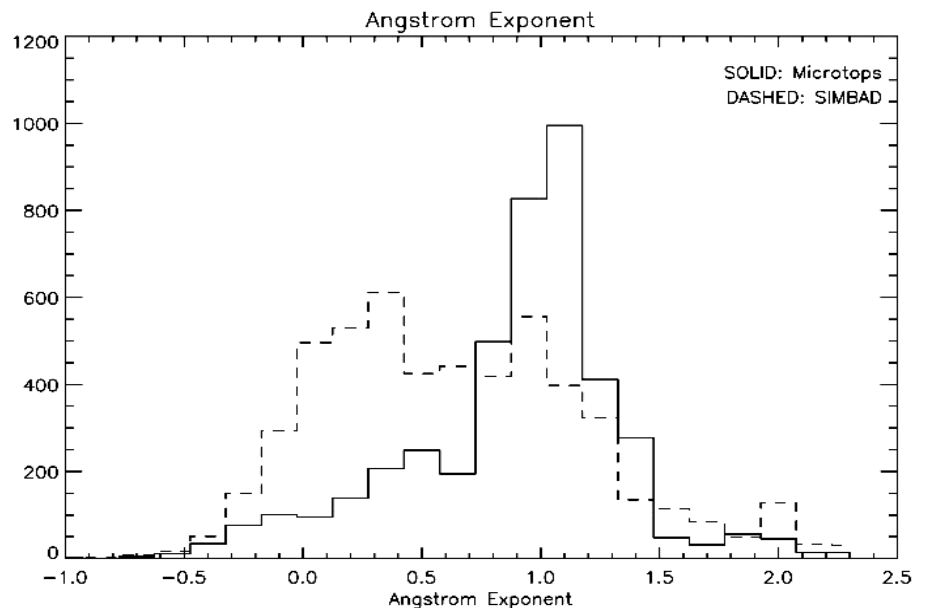
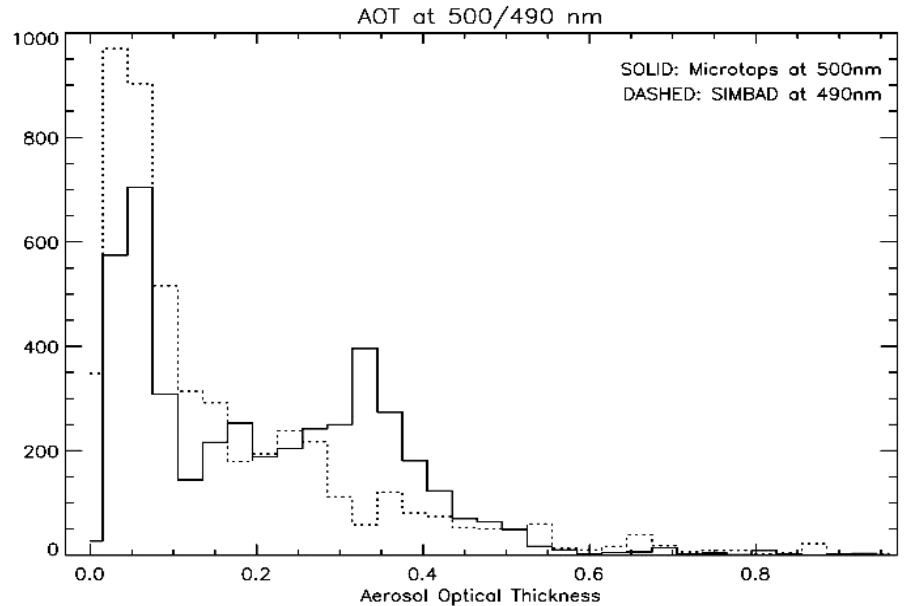
- Next step: applications

- Divide data into thematic groups (maritime, coastal, etc.)

- Assist with creation of new maritime atmospheric correction models

- Validation matchups with Ocean Color satellites

- Identify marine aerosol AERONET sites

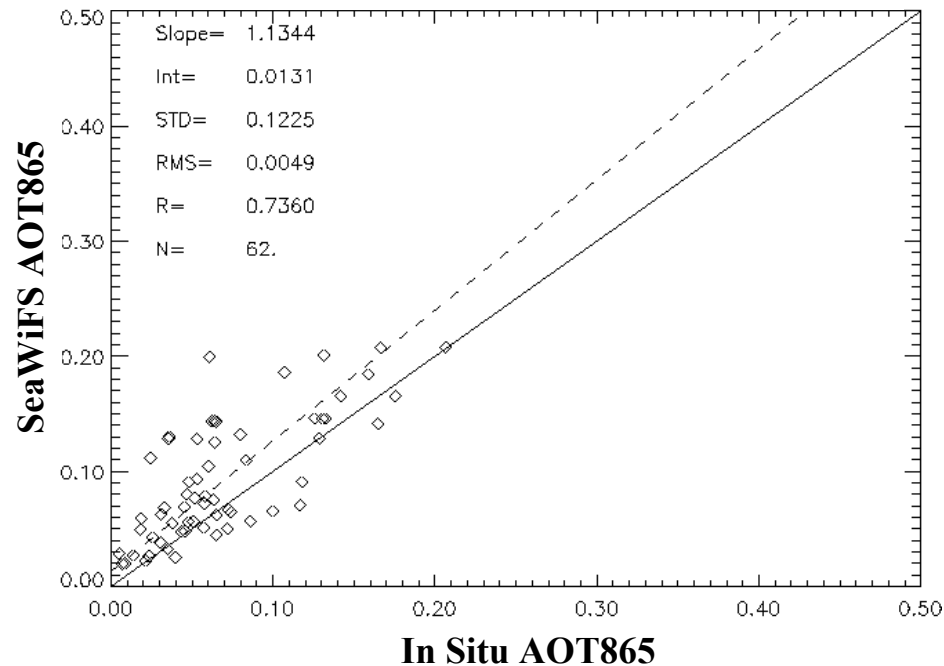


# Matchup Results - *hand held sun photometers*

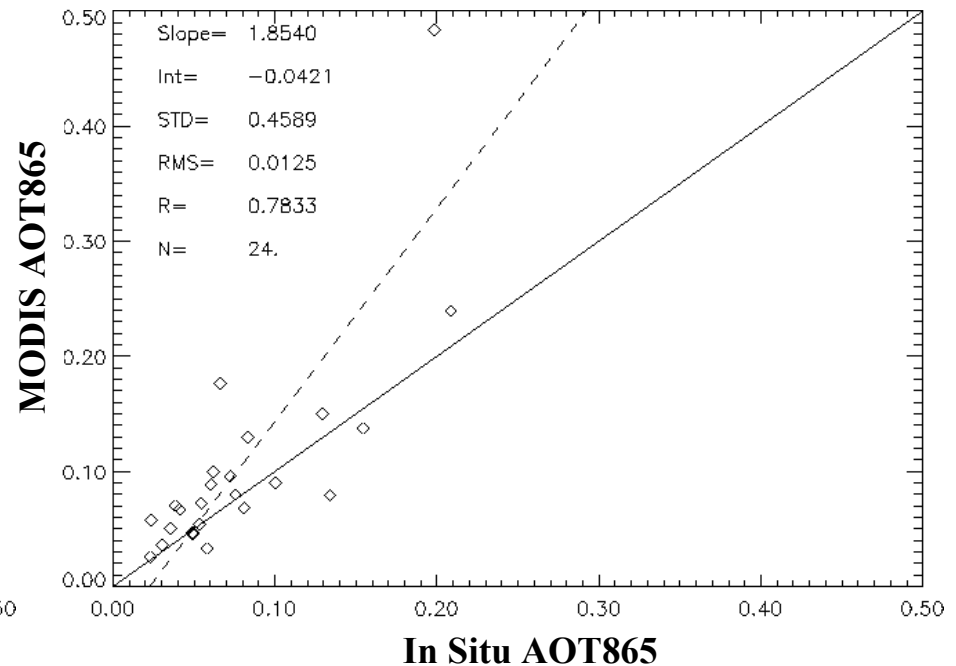
In Situ data is matched to spatially and temporally concurrent satellite data

**Below are matchups for open ocean data collected with the SIMBAD and Microtops II for AOT at 865nm**

**SeaWiFS - In Situ matchups for AOT at 865nm**



**MODIS Terra - In Situ matchups for AOT at 865nm**

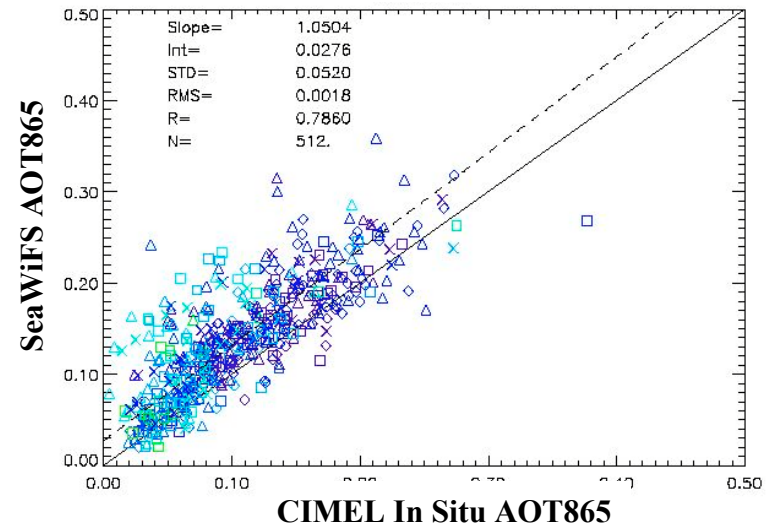


# Matchup Results - *CIMEL sun photometers*

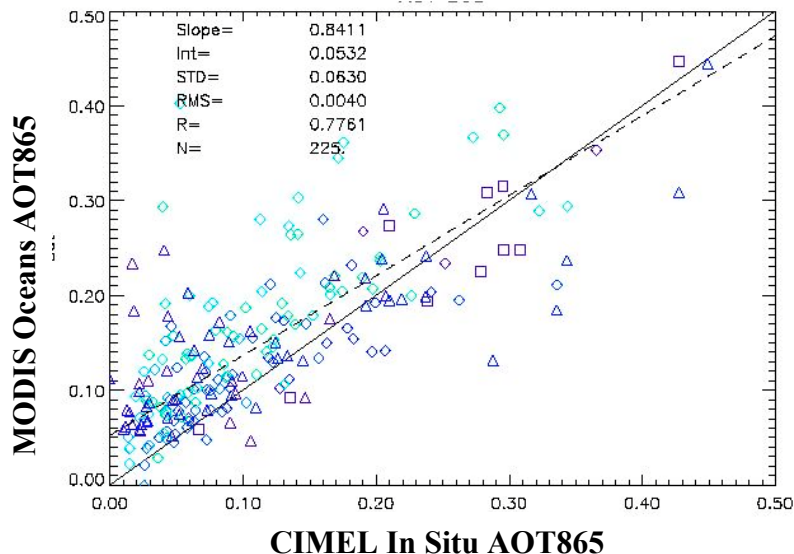
**In Situ data is matched to spatially and temporally concurrent satellite data**

**Below are matchups for coastal data collected with the AERONET/SIMBIOS CIMELS**

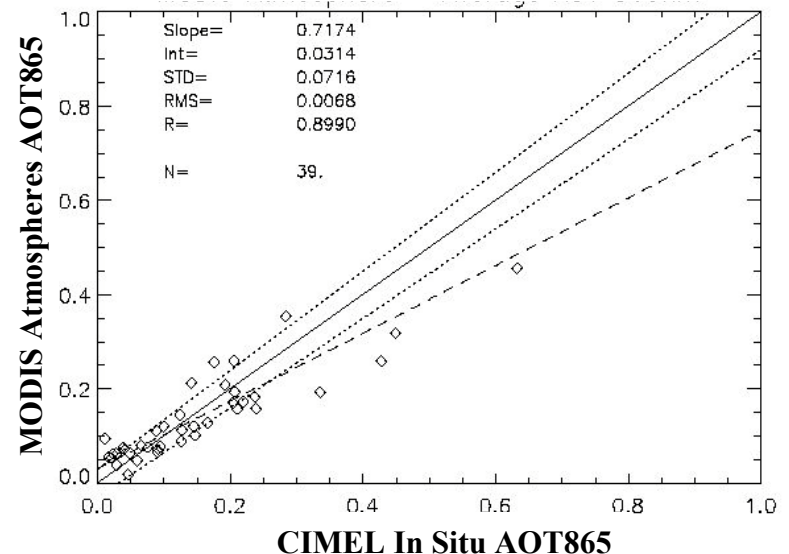
**SeaWiFS - In Situ matchups AOT at 865nm**



**MODIS Oceans - In Situ matchups AOT at 865nm**



**MODIS Atmospheres - In Situ matchups AOT at 865nm**

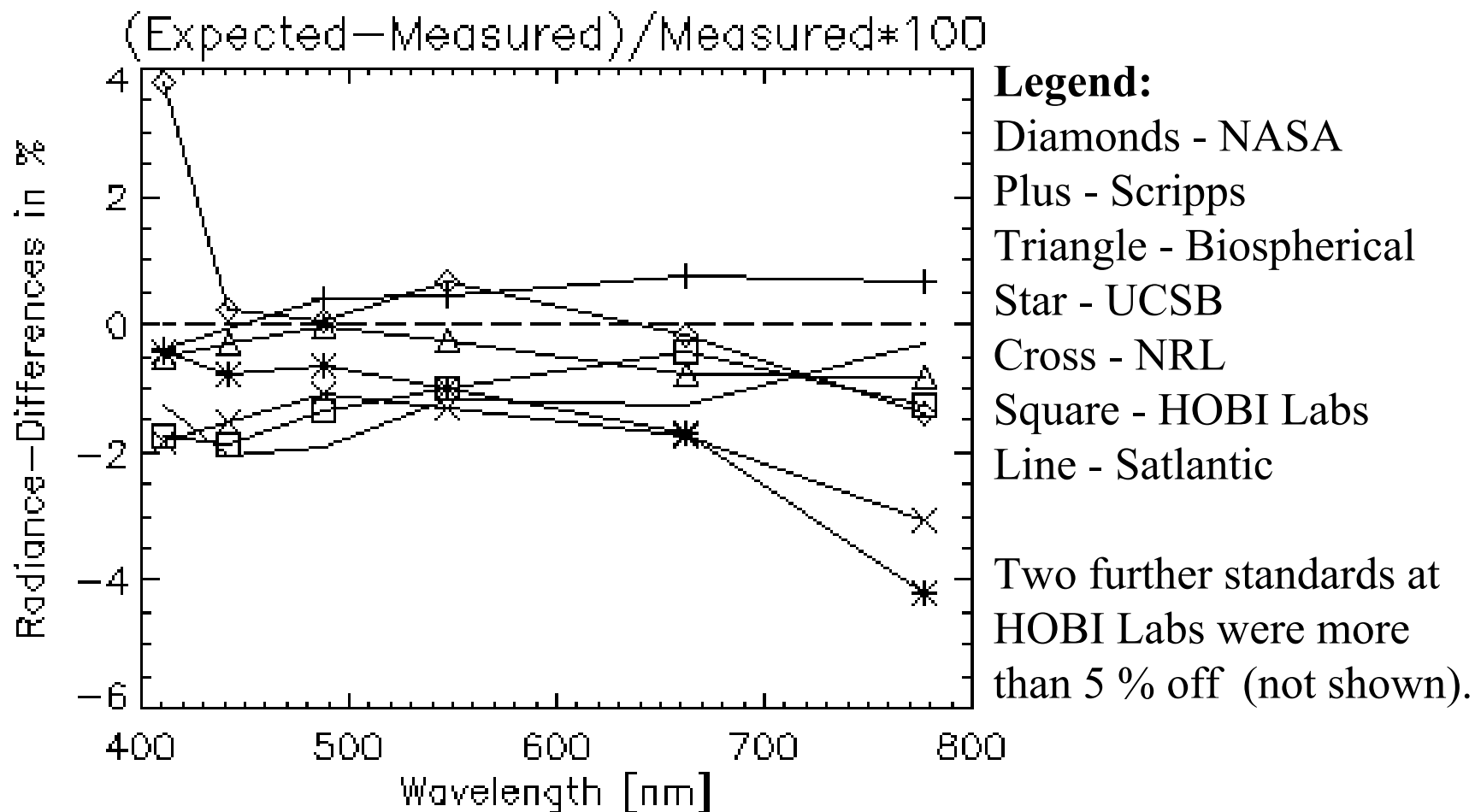


## Goals of the SIMBIOS Radiometric Intercomparison (SIMRIC)

- Verify that all laboratories are on the same radiometric scale
- Document the calibration protocols (c.p.)
- Encourage the use of standardized c.p.
- Identify where the c.p. need to be improved

RR's supported to date by SeaWiFS & SIMBIOS Projects (1992-1993-1996-1998-1999-2001 & 2002)

# SIMRIC-1 Comparison Results (2001)



## Web References

<http://simbios.gsfc.nasa.gov/>

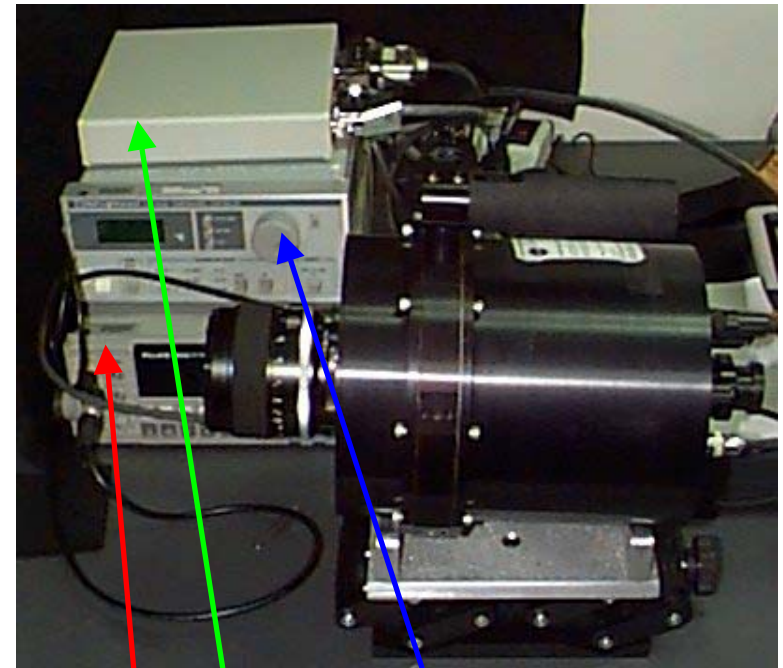
<http://seawifs.gsfc.nasa.gov/seawifs.html>



extra

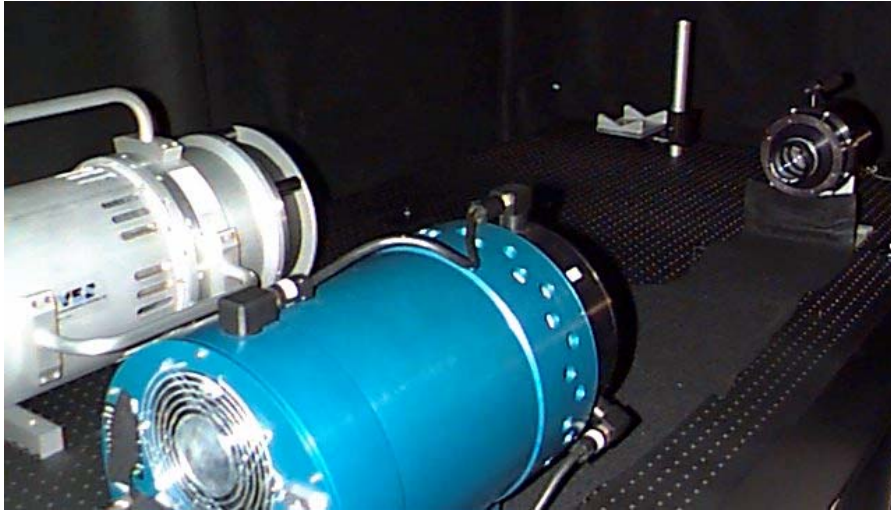
# The SeaWiFS Transfer Radiometer (SXR-II)

- The SXR-II is a six channel filter radiometer designed by NIST to measure radiance.
- Wavelength coverage: 412nm to 777nm.
- It is calibrated once a year (starting in 2000) on the NIST SIRCUS facility (C. Johnson, S. Brown).



Voltmeter  
Control-Box  
Temperature-Controller  
(connects to laptop)

# SeaWiFS Quality Monitor: SQM



SQM from YES Inc. (left) and SQM-II from Satlantic (right). SXR-II views SQM exit aperture (hidden).

- The SQM was designed by NIST and NASA as a portable light source to monitor the stability of radiometers during ship cruises.
- The SIMBIOS Project uses two commercially available SQMs to monitor the stability of the SXR-II between the NIST calibrations.

A 2 % variation in SXR-II channel 1 during 2001 was detected.

## Method for comparing radiances:

- The *radiances measured* by the SXR-II are compared to the *radiances expected* by the laboratories
- The SXR-II measured radiance is calculated as measured voltage times calibration factor for each channel.
- The expected radiance  $L_e$  for each channel is calculated as the integral over wavelength of the product of the calibration radiance  $L$  (provided by the laboratory) times the normalized responsivity  $R$  of the respective SXR-II channel (known from the SIRCUS calibration):

$$L_e = \int L(\lambda) \cdot R(\lambda) d\lambda$$